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(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 797 002 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
24.09.1997 Bulletin 1997/39

(51) Int Cl.6: F04C 11/00

(21) Application number: 97301811.2

(22) Date of filing: 18.03.1997

(84) Designated Contracting States:
DE ES FR GB IT NL SE

(30) Priority: 21.03.1996 GB 9605941

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(54) **Rotary positive displacement hydraulic machines**

(57) A rotary positive displacement hydraulic machine in the form of a gear pump or motor comprises a housing 10 incorporating two axially extending working chambers 11 and 12 arranged with their axes parallel to one another, and first and second gears 24, 25 and 27, 28 mounted in each chamber for rotation about the chamber axis to effect fluid pumping. Each gear in each chamber forms a meshing pair with a respective one of the gears in the other chamber. The first and second gears in each chamber are mounted so that their gear teeth are out of phase by about a quarter of a tooth pitch relative to one another. The gear teeth of the two gears of each meshing pair mesh with one another in such a manner that each tooth of each gear engages the flanks of two adjacent teeth of the other gear simultaneously along two parallel lines of contact.

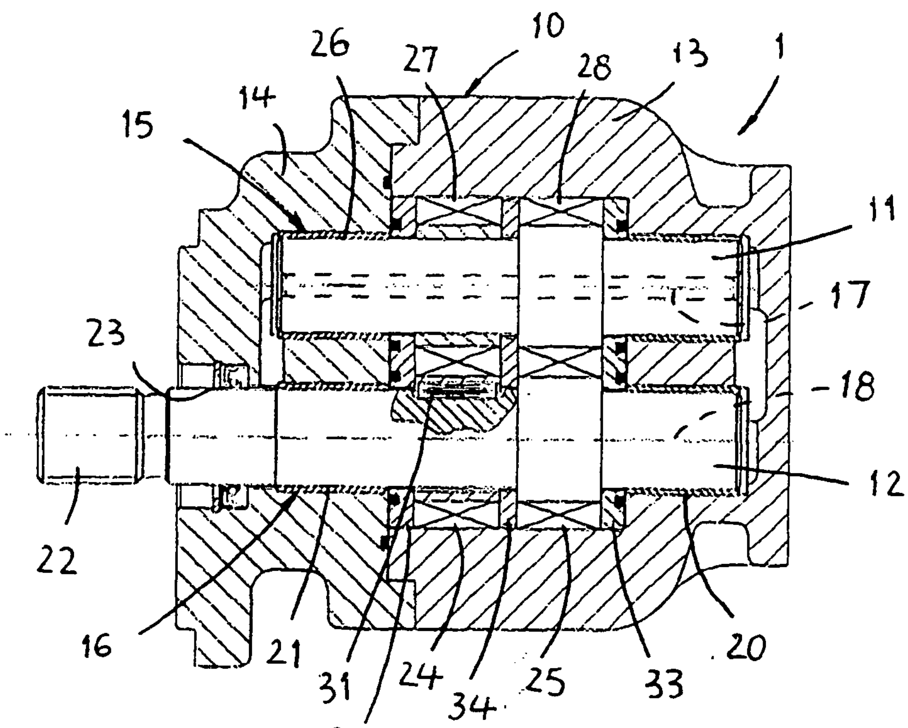

FIG. 2

Description

This invention relates to rotary positive displacement hydraulic machines, such as gear pumps and motors.

Rotary positive displacement hydraulic machines in the form of gear pumps and motors generally comprise a housing having two mutually intersecting and axially extending working chambers arranged with their axes parallel to one another, and two meshing gears mounted for axial rotation in respective chambers to effect pumping of fluid from an inlet to an outlet.

The source flow characteristics of external involute gear pumps and motors determine the fluid borne noise generation of such machines and are the prime source of air borne noise from hydraulic systems in which they are used. In general machines which excite the lowest number of frequencies will produce the quietest systems. Most gear pumps and motors are characterised by noise of the first four harmonics of gear tooth frequency, that is the first harmonic, the second harmonic at a quarter of the amplitude of the first harmonic, the third harmonic at a ninth of the amplitude of the first harmonic and the fourth harmonic at a sixteenth of the amplitude of the first harmonic.

It is known to provide a gear pump or motor with two equal gears separated by a centre plate in each working chamber such that each gear in each chamber forms a meshing pair with an associated one of the gears in the other chamber, the gears being in single flank contact (with backlash), and such that the gear teeth of the two gears in each chamber are in antiphase to one another (equivalent to 180° phase shift at the first harmonic frequency). Such an arrangement produces a parabolic flow variation at twice the tooth frequency by cancelling the odd harmonic frequency components which would otherwise be provided. Thus the noise output of such machines is characterised by a second harmonic frequency component at a quarter of the amplitude of the first harmonic component (which would otherwise be produced) and a fourth harmonic frequency component at a sixteenth of the amplitude of the first harmonic component.

It is also known, as an alternative to such an arrangement, to utilise dual flank contacting meshing gears (with no backlash), in which each tooth of each meshing gear engages the flanks oftwo adjacent teeth of the other meshing gear simultaneously along two parallel lines of contact in order to produce a parabolic flow variation at twice the tooth frequency and a quarter of the amplitude of a single flank contacting arrangement with backlash, that is a flow variation with similar harmonic components to the previously described arrangement.

Whilst both ofthe above arrangements have been used separately to provide low noise gear pumps and motors, such low noise gear pumps and motors are still capable of producing significant noise under certain conditions.

It is an object of the invention to provide an improved low noise gear pump or motor.

According to the present invention there is provided a rotary positive displacement hydraulic machine in the form of a gear pump or motor comprising a housing incorporating two axially extending working chambers arranged with their axes parallel to one another, and first and second gears mounted in each chamber for rotation about the chamber axis to effect fluid pumping, each gear in each chamber forming a meshing pair with a respective one of the gears in the other chamber, wherein the first and second gears in each chamber are mounted so that their gear teeth are out of phase by about a quarter of a tooth pitch relative to one another, and wherein the gear teeth ofthe two gears of each meshing pair mesh with one another in such a manner that each tooth of each gear engages the flanks of two adjacent teeth of the other gear simultaneously along two parallel lines of contact.

It should be understood that the gear teeth of the first and second gears are ideally out of phase by exactly a quarter of a tooth pitch equivalent to 90° phase shift at the first harmonic frequency, but that manufacturing tolerances may cause this phase shift to vary from the ideal value, for example in the range of 80° to 100°.

The effect of phasing the two gears in each chamber such that their gear teeth are out of phase by about a quarter of a tooth pitch will have the effect of substantially cancelling the odd harmonic frequency components remaining after cancellation of the original odd harmonic frequency components due to the dual flank arrangement contacting of the meshing gears (with no backlash), so that only the fourth harmonic frequency component at a sixteenth of the amplitude of the first harmonic component will remain. Thus such an arrangement will allow hydraulic power transmission with substantially no fluid borne noise generation at the first three harmonics of the tooth frequency.

The invention also provides a rotary positive displacement hydraulic machine in the form of a gear pump or motor comprising a housing incorporating two axially extending working chambers arranged with their axes parallel to one another, and first and second gears mounted in each chamber for rotation about the chamber axis to effect fluid pumping, each gear in each chamber forming a meshing pair with a respective one of the gears in the other chamber, wherein the first and second gears in one of the chambers are mounted on a common shaft so that their gear teeth are out of phase by a quarter of a tooth pitch relative to one another, and wherein the first and second gears in the other chamber are journalled in respective bearings so as to be separately rotatable.

In order that the invention may be more fully understood, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 is an explanatory diagram;
Figure 2 is an axial section along the line II-II in Figure 3 of a first gear pump in accordance with the invention;
Figure 3 is a cross-section along the line III-III in Figure 2; and
Figures 4 to 7 are axial sections of second, third, fourth and fifth gear pumps in accordance with the invention.

Figure 1 shows a dual flank contacting arrangement in which two meshing gears 2 and 3 of a gear pump engage one another such that a gear tooth 4 of one of the gears contacts the flanks of two adjacent gear teeth 5 and 6 of the other gear simultaneously along two parallel lines of contact 7 and 8 extending parallel to the gear axes. As previously described, such a dual flank contacting arrangement (with no backlash) produces a parabolic flow variation at twice the tooth frequency and one quarter of the amplitude of a single flank contacting arrangement (with backlash). This results in cancellation of the odd harmonic frequency components which would otherwise be produced using a single flank contacting arrangement.

Figures 2 and 3 show a pot-bodied gear pump 1 typically formed of cast iron and comprising a housing 10 consisting ofa pot body 13 and an end cover 14 clamped to the body 13 by bolts 19. Two meshing pump rotors 15 and 16 are mounted for rotation about axes 17 and 18 within two intersecting working chambers 11 and 12 formed within the pot body 13, each rotor being journalled within sleeve bearings 20 and 21 received within the body 13 and cover 14.

The pump rotor 16 comprises a drive shaft 22 extending through an aperture 23 in the cover 13, and first and second gears 24 and 25 mounted on the drive shaft 22. Furthermore the pump rotor 15 comprises a driven shaft 26 and first and second gears 27 and 28 mounted on the driven shaft 26. The body 10 is formed at its closed end with a low pressure or inlet port 29 and a high pressure or outlet port 30, each of which communicates with both working chambers 11 and 12.

The first gears 24 and 27 ofthe two rotors 15 and 16 are in dual flank contacting meshing engagement (with no backlash) as described above, and the second gears 25 and 28 of the two rotors are also in such dual flank contacting engagement. Furthermore each ofthe second gears 25 and 28 is integral with the associated drive or driven shaft 22 or 26, and the first gear 24 is mounted on the shaft 22 by a key 31 so as to have a defined phase relationship with the second gear 25 on the same shaft in which the gear teeth of the two gears are out of phase by a quarter of a tooth pitch relative to one another, the first gear 27 being freely rotatable on the shaft 26. Each set of gears 24 and 25 or 27 and 28 are held between two pressure balancing plates 32 and 33 with a small degree of axial freedom, and in addition the first and second gears 24 and 25 or 27 and 28 is separated in each case by a centre plate 34 which maintains the fluid flows pumped by the two gears separate. The mounting of the first gears 24 and 27 on the shafts 22 and 26 permits axial displacement of the gears 24 and 27 to engage the centre plate 34 under fluid pressure in order to promote sealing between the two pumped flows.

Such a dual gear arrangement with balance plates and dual flank contacting allows hydraulic power transmission with substantially no fluid borne noise at the first three harmonics of tooth frequency so that the gear pump is particularly quiet in operation.

Furthermore a similar arrangement may be applied to a more conventional form of gear pump 40 as shown in Figure 4 in which the housing 41 has a generally cylindrical body 42 provided with two end covers 43 and 44 closing opposite ends of the body 42, aluminium bushes 45 and 46 being provided within the body to define the two ends of each chamber 11 or 12 in each case. The arrangement is otherwise the same as that provided in the pot-bodied pump of Figure 2, and similar parts are denoted by the same reference numerals in each case.

Figure 5 shows a tandem construction 50 effectively corresponding to two pot-bodied pumps placed back-to-back but having a common housing 51 formed from a single cast body 52 provided with end covers 53 and 54, and having two differently sized pump sections provided on a common drive shaft 55. Each pump section comprises a single gear 56 or 57 mounted on the drive shaft 55 with a defined phase relationship, and a further gear 58 or 59 meshing with the gear 56 or 57 and integral with a respective driven shaft 60 or 61. Each ofthe gears 56, 57, 58 and 59 is held between two pressure balancing plates 62 and 63 with a small degree of axial freedom, the gear 57 being located on the shaft 55 by a key 64 permitting relative axial movement between the gears 56 and 57. The phasing ofthe gear pairs is accurately controlled by the mounting of the gears 56 and 57 on the common shaft 55 such that their gear teeth are out of phase by a quarter of a tooth pitch relative to one another. Such a phasing arrangement allows reduction in amplitude of the odd frequency harmonics which would otherwise be produced in the absence of such a phase relationship when the outputs of the two pump sections are combined (or allows cancellation of these harmonics altogether in the case in which the two pump sections are of the same size), and avoids the need for accurate location of interengaging splines as would be required if the drive shaft consisted of two parts for the two pump sections requiring coupling together by interengaging splines. Such a tandem construction may have inlets and outlets which are either separate or coupled together, and the pump (or motor) may be uni-rotational or bi-rotational.

Figure 6 shows a tandem construction 65 which is similar to that of Figure 5 except that first and second gears 66 and 67 having gear teeth which are out of phase by a quarter of a tooth pitch relative to one an-

other are provided on the drive shaft 55 in each pump section, a centre plate 68 being provided between the first and second gears 66 and 67 in each case and the first and second gears 66 and 67 being in dual flank contacting meshing engagement with first and second gears 69 and 70 separated by a centre plate 71 and mounted on the driven shaft 60 or 61. The common drive shaft 55 allows control ofthe phase relationship between the first and second gears 66 and 67 of each pump section as well as between the gears of the two pump sections, and the mounting of three of these gears on the shaft 55 by keys 72 allows relative axial movement between the gears to promote fluid sealing between the separate fluid flows of the gears. The combination of the phasing ofthe first and second gears 66 and 67 and the dual flank contacting arrangement allows cancellation of the first three frequency harmonics of the tooth frequency in each pump section in a manner similar to that described above with reference to the embodiments of Figures 2 to 4. Furthermore, if the outputs of the two pump sections are combined and if the phasing of the first and second gears 66 and 67 of one pump section is offset by an eighth of a tooth pitch relative to the phasing of the first and second gears 66 and 67 of the other pump section, the fourth frequency harmonic can also be cancelled leaving the eighth frequency harmonic as the lowest remaining harmonic.

Figure 7 shows a pump construction 74 having a housing 75 consisting of a cylindrical body 42 and end covers 43 and 44 of generally similar form to the embodiment of Figure 4 except that, in this case, two pump sections are provided having gears 56 and 57 mounted on a common drive shaft 55 in a defined phase relationship such that their gear teeth are out of phase by a quarter of a tooth pitch relative to one another and meshing with further gears 58 and 59 mounted on respective driven shafts 60 and 61. Each gear is held between respective bushes 45 and 46, and the two pump sections are optionally separated by a separating plate 76. In this embodiment the inlets and outlets of the two pump sections are combined, and the defined phase relationship of the two pump sections allows cancellation of the odd frequency harmonics which would otherwise be produced in the absence of such a phase relationship.

Claims

1. A rotary positive displacement hydraulic machine in the form of a gear pump or motor comprising a housing (10) incorporating two axially extending working chambers (11,12) arranged with their axes parallel to one another, and first (24,27) and second (25,28) gears mounted in each chamber for rotation about the chamber axis to effect fluid pumping, each gear in each chamber forming a meshing pair with a respective one of the gears in the other chamber, wherein the first and second gears in each chamber are mounted so that their gear teeth are out of phase by about a quarter of a tooth pitch relative to one another, and wherein the gear teeth of the two gears of each meshing pair mesh with one another in such a manner that each tooth of each gear engages the flanks oftwo adjacent teeth of the other gear simultaneously along two parallel lines of contact.

2. A machine according to claim 1, wherein the first and second gears (24 and 25; 56 and 57; 66 and 67) in one of the chambers are mounted on a common shaft (22; 55) so that their gear teeth are out of phase by about a quarter of a tooth pitch relative to one another.

3. A machine according to claim 2, wherein the first and second gears (27 and 28) in the other chamber are mounted on a common shaft (26) so that their gear teeth are out of phase by about a quarter of a tooth pitch relative to one another.

4. A machine according to claim 2, wherein the first and second gears (58 and 59) in the other chamber are journalled in respective bearings so as to be separately rotatable.

5. A machine according to any preceding claim, wherein a centre plate (34; 68;76) is interposed between the first and second gears in each chamber for separating the fluid flows pumped by the two gears.

6. A machine according to claim 5, wherein at least one of the first and second gears is slidable axially to engage the centre plate under fluid pressure.

7. A machine according to any preceding claim, which is of tandem construction and comprises two pump sections, each of which comprises two pairs of meshing gears (66,67 and 69,70) with the two gears of each pair being disposed in different working chambers, wherein the first and second gears in each chamber are mounted so that their gear teeth are out of phase by about a quarter of a tooth pitch relative to one another, and wherein the gear teeth of the two gears of each pair mesh with one another in such a manner that each tooth of each gear engages the flanks of two adjacent teeth of the other gear simultaneously along two parallel lines of contact.

8. A machine according to claim 7, wherein the first and second gears (66,67) in one of the chambers of one of the pump sections and the first and second gears in one of the chambers of the other pump section are mounted on a common shaft (55) in a defined phase relationship.

9. A machine according to any one of claims 1 to 8, wherein the working chambers are defined by two parallel intersecting bores formed in a one-piece body forming part of the housing.

10. A machine according to any one of claims 1 to 8, wherein the working chambers are defined by bushes (45,46) inserted into receiving recesses formed in the housing.

11. A rotary positive displacement hydraulic machine in the form of a gear pump or motor, comprising a housing incorporating two axially extending working chambers arranged with their axes parallel to one another, and first (56 and 58) and second gears (57 and 59) mounted in each chamber for rotation about the chamber axis to effect fluid pumping, each gear in each chamber forming a meshing pair with a respective one of the gears in the other chamber, wherein the first and second gears (56 and 57) in one of the chambers are mounted on a common shaft (55) so that their gear teeth are out of phase by about a quarter of a tooth pitch relative to one another, and wherein the first and second gears (58 and 59) in the other chamber are journalled in respective bearings so as to be separately rotatable.

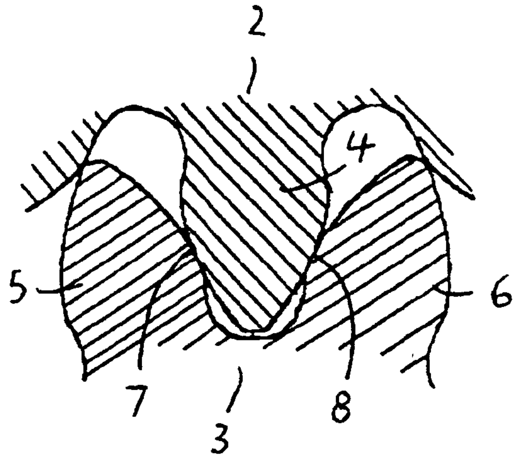

FIG.1

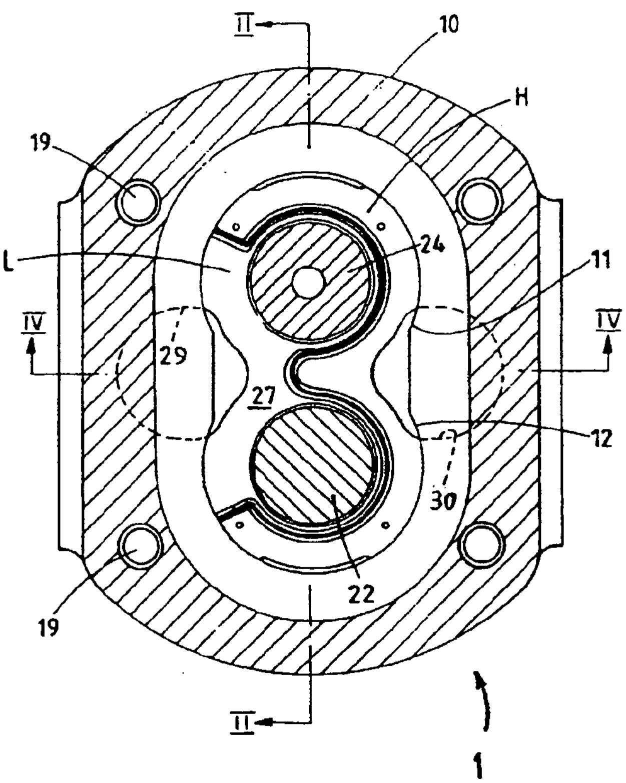

FIG.3.

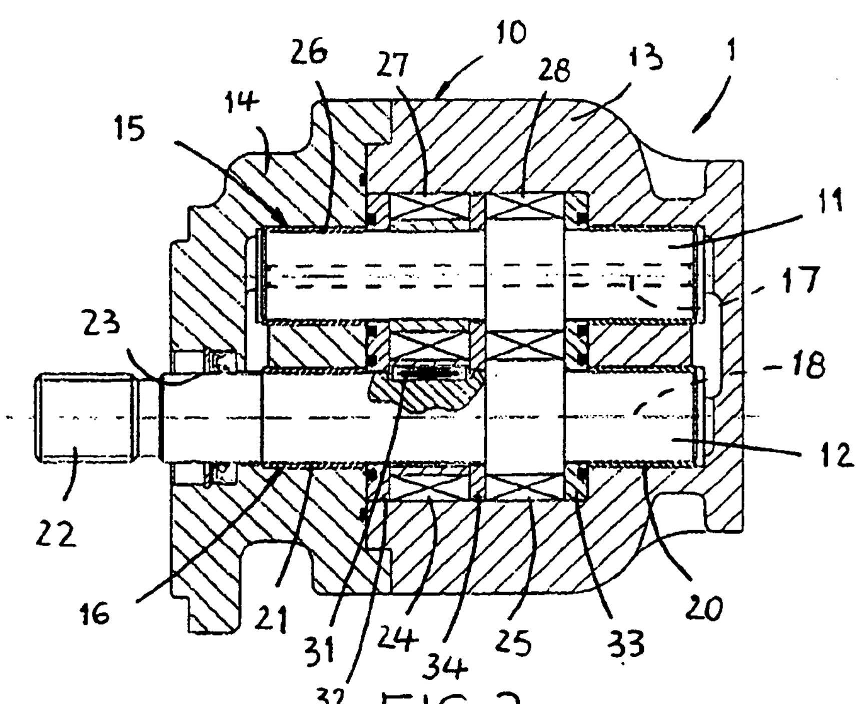

FIG.2

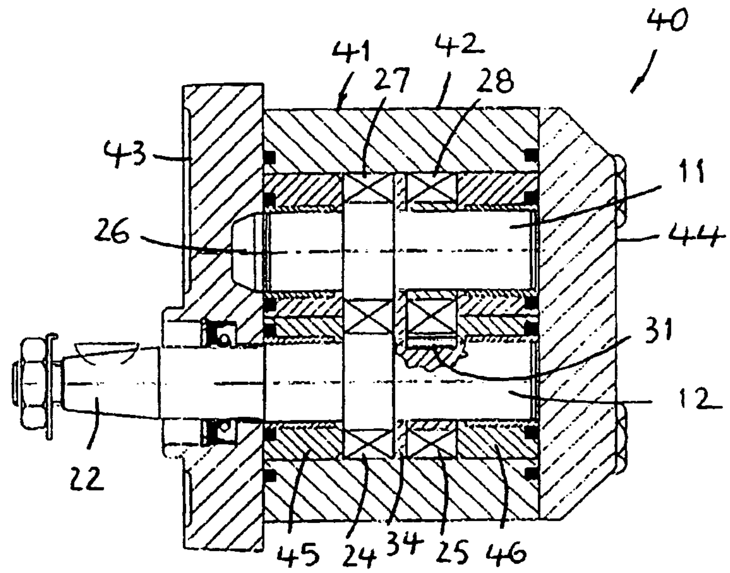
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FIG.4

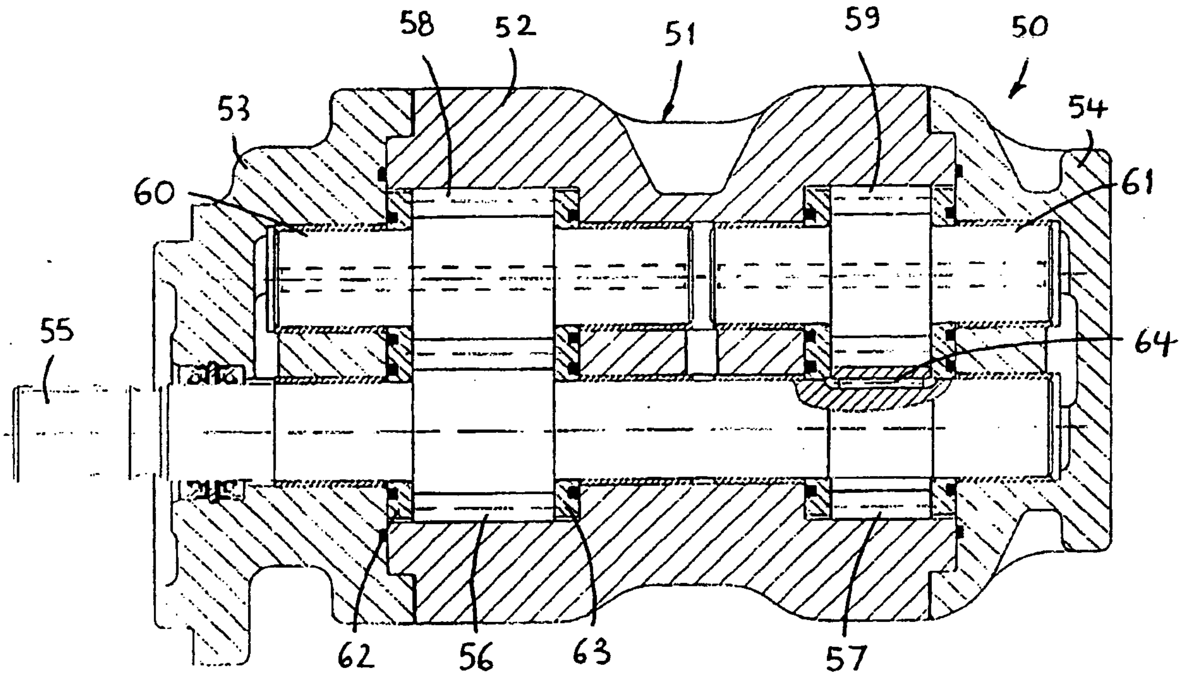
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FIG.5

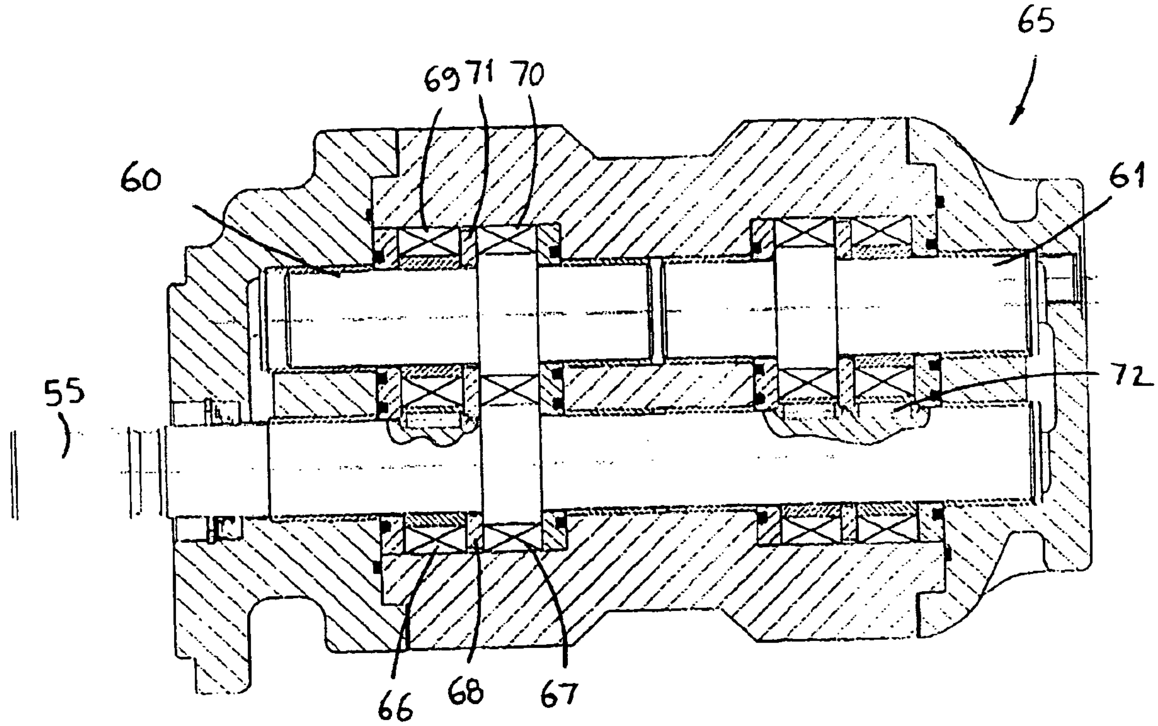
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FIG.6

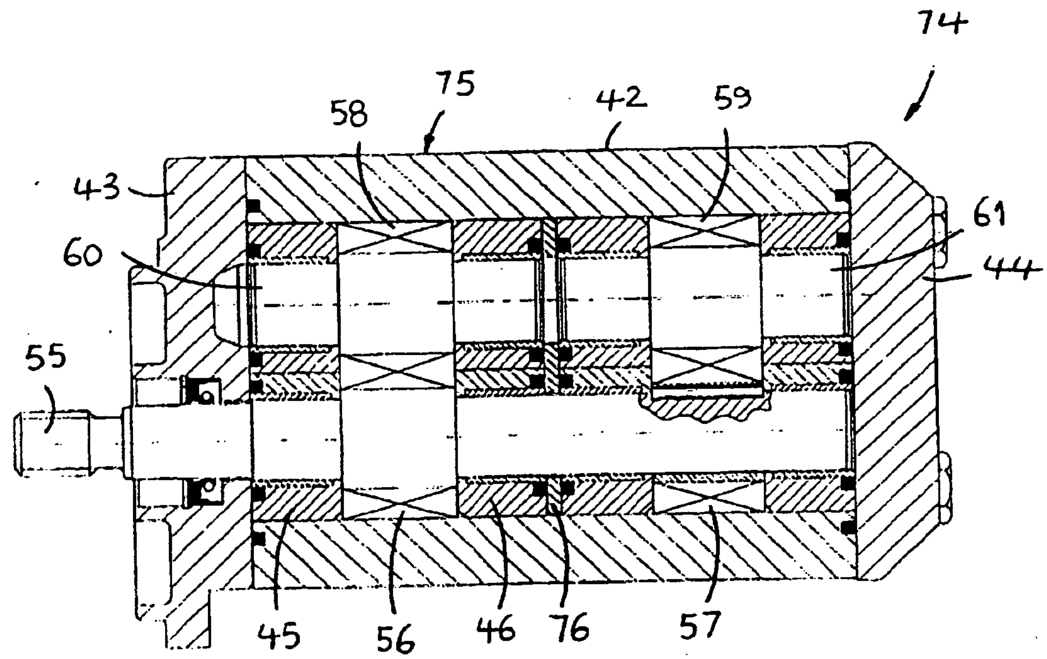
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FIG.7

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EUROPEAN SEARCH REPORT

Application Number
EP 97 30 1811

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X Y	EP 0 004 119 A (KORSE) * page 1 - page 2 * * page 4, line 7 - page 7, line 34; figures *	1-3,5,9, 10 4,6,7,11	F04C11/00
Y	US 4 259 045 A (HIDEO TERUYAMA) * column 2, line 56 - column 3, line 52; figures 1,2 *	4,11	
Y	US 2 931 302 A (DLUGOS) * the whole document *	6,7	
A	FR 2 231 865 A (VEB INDUSTRIEWERKE KARL-MARX STADT) * page 5, line 3 - page 6, line 32; figures *	1,6	
A	GB 2 254 376 A (KAYABA INDUSTRY CO. LTD.) * page 1, line 8 - page 4, line 9; figure 4 * * page 4, line 29 - page 6, line 1; figures 1-3 *	1,4,6, 9-11	TECHNICAL FIELDS SEARCHED (Int.Cl.6) F04C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	3 July 1997	Kapoulas, T

CATEGORY OF CITED DOCUMENTS

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